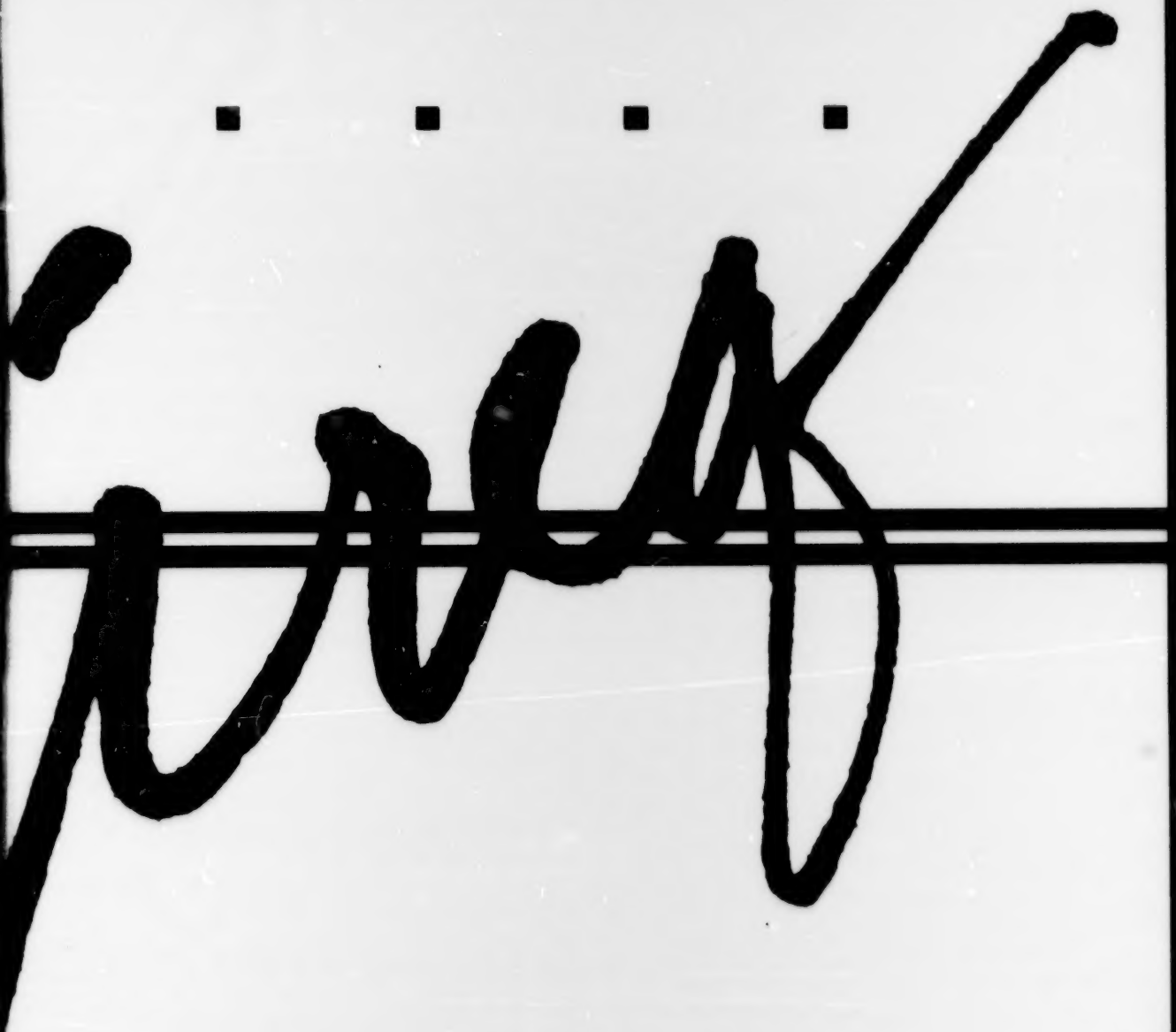
REPORT of ACTIVITIES 1983



Institut de recherche
d'Hydro-Québec

LIST OF ACRONYMS

ACFAS	Association canadienne-française pour l'avancement des sciences (Québec)
ASTM	American Society for Testing and Materials
CCV	Canadian Consultants for Venezuela
CEA	Canadian Electrical Association
CEPEL	Centro de Pesquisas de Energia Elétrica (Brazil)
CIDA	Canadian International Development Agency
CODATEL	Corporation de développement et d'application de technologies électriques (Québec)
DAMP	Distnaziatori Ammortizzatori Smorzatori Vibrazoni e Morsetterie per Linee Elettriche (Italy)
EDELCA	Electrificación del Caroni C.A. (Venezuela)
EDF	Électricité de France
ENDESA	Empresa Nacional de Electricidad S.A. (Chile)
EPRI	Electric Power Research Institute (U.S.)
INRS-ÉNERGIE	Institut national de la recherche scientifique (Québec)
MIT	Massachusetts Institute of Technology (U.S.)
NEPOOL	New England Power Pool (U.S.)
NRC	National Research Council (Canada)
SIDBEC	Sidérurgie Québec
SNEA	Société nationale Elf-Aquitaine (France)
SNÉMO	Société de négoce, d'études électriques et électroniques, de matériel et d'outillage (Québec)

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MESSAGE

from the Executive Vice-President, Technology and International Affairs

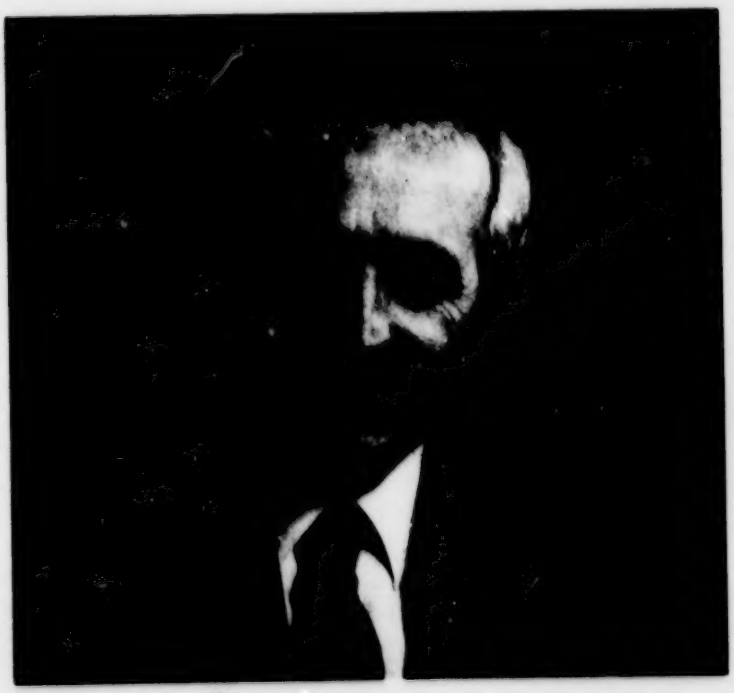
Since taking up this position in September, I have realized how greatly Hydro-Québec has changed since I left IREQ in 1978. I see the utility in mid-metamorphosis as it finds itself obliged to broaden its horizons and diversify its activities. Hydro-Québec can no longer restrict itself to the generation, transmission, distribution and sale of electricity to its traditional customers; it must place greater emphasis on marketing its energy and exploiting its technology and expertise.

These objectives have naturally affected the activities of the Technology and International Affairs division. In view of the company's new situation, it is essential to define research and development priorities that will enable the utility to meet its technological requirements and maintain its position as one of the driving forces in Québec's development.

It was with this in mind that I recently initiated a far-reaching program of consultation with representatives from IREQ and other departments of the company in order to formulate a technology development and marketing strategy for Hydro-Québec. In addition, task forces have been created to determine the company's development policies for a number of key technological areas for the next 10 to 15 years and to propose ways which will permit the utility to achieve its goals and benefit from commercialization and

technological opportunities that will arise over this period. IREQ will obviously have a leading role to play in drawing up these strategies and in carrying out the research and development programs which will be identified.

To achieve these objectives, I am therefore counting on the collaboration of the new vice-president of IREQ, Toby Gilsig, and the personnel of the Institute, who together in the past year have devoted considerable effort to redefining the Institute's activities in terms of the utility's new environment.



Gilles Cloutier

PRESENTATION

by the Vice-President, IREQ

The past year has witnessed a wealth of achievements in all areas of activity.

The modification of IREQ's organization to meet Hydro-Québec's new preoccupations led, among other things, to the formation of a multidisciplinary team in the field of industrial applications of electricity and to the grouping of energy-production and utilization activities in a single department.

The objectives of our programs were re-examined so as to orient the Institute's activities towards increasing productivity and improving the quality of customer service as well as towards developing efficient, cost-effective applications of electricity in the industrial sector.

In pursuit of its aim to promote the development and application of electrical technologies in Québec industries, IREQ purchased plasma technology developed by Noranda and also initiated projects with industrial partners to study and set up pilot plants that will utilize these technologies. For example, agreements have been signed with *CODATEL* in Québec to build test benches for plasma and infrared technologies. In France, agreements have been signed with *EDF* in the area of industrial applications of electricity, and with *SNEA* for the development of high-energy-density batteries.

To increase the efficiency and reliability of Hydro-Québec's power system, we have also invested significant effort related to interconnections and, last July, we commissioned a synthetic test circuit in the high-power laboratory for performing major tests on electrical equipment. This test circuit supplies voltage and power levels of the order of 2000 kV and 7000 MVA during out-of-phase interrupting tests on complete poles of 735-kV circuit breakers.

Concerning other new facilities, work progressed on the *EOLE* and Tokamak projects: 1983 saw the erection of a 56-kW Darrieus wind turbine at IREQ as well as the initial stages in the installation of the Varennes tokamak machine. A radioisotope laboratory has also been set up in cooperation with other Hydro-Québec departments.

A substantial effort was devoted to promoting techniques and products developed at Hydro-Québec. Several contracts have been signed with CEA and EPRI, for instance, which should speed up the development of economically viable technologies and processes. Marketing efforts have led to sales of the overhead-ground-wire power tap in Peru and of the Institute's digital power system analysis programs to the Central Electricity Authority in India. In addition to increased participation in international technology-transfer fairs in 1983, we published a brochure on the research undertaken at the Institute as well as a newsletter, *Information IREQ*, both of which are addressed to our clients and partners in Hydro-Québec, the electrical industry and the scientific community at large.

These achievements would have been impossible without the cooperation, expertise and enthusiasm of our personnel. To mention just a few of the honors bestowed upon my colleagues over the past year, the IEEE's W.R.G. Baker prize was won by Ryszard Malewski and Chinh Trung Nguyen, both research scientists at IREQ, while Guy Bélanger received the J.A. Bombardier prize awarded by ACFAS, Farouk A.M. Rizk was named Chairman of the IEC Study Committee on Insulation Coordination, P. Sarma Maruvada became a Fellow of the IEEE, and Raymond Bartnikas, a well-known authority on materials, was made a Research Fellow of IREQ.

In closing, I would like to thank all the directors and managers, as well as the scientific and administrative personnel of IREQ, for their contributions to the success of our company and the reputation of our Institute.

Toby Gilsig

POWER TRANSMISSION

Director
Farouk A.M. Rizk

The activities of the Power Transmission department are related mainly to dielectric phenomena, mechanical vibration and the impact of electric power systems on the environment.

The bulk of the research on external insulation in 1983 dealt with the development of DC test techniques for testing insulators both in the field and in the laboratory, analysis of the interaction between polluted insulators and AC test sources, and a study of the dielectric strength of air at high altitudes. Another aim pursued was to determine the air clearances for power lines supplying electric railways.

The past year has also seen various studies on the internal insulation of electric power system equipment. At the request of CEA, for example, an analysis of the dielectric strength of transformers with 17 to 25 years' service was undertaken, along with aging tests on cables and other distribution equipment subjected to ringing switching surges. Research was also conducted for CEA on the breakdown voltage/time characteristic of spacer-equipped SF_6 cables when subjected to steep-front impulses. Still in the area of internal insulation, an attempt has been made to assess the feasibility of the direct use of a 25-kV power supply for industrial water-resistance boilers.

One of the salient achievements in the department's research into line mechanics and vibration in 1983 was the completion of a program of tests to evaluate spacer-dampers on the Magdalen Islands experimental line for *EDELCA* and the performance of 25 000 hours' testing on composite insulators to study the time dependence of failure.

With regard to the environmental impact of electric power systems, the department began a long-term study of a ± 450-kV DC line configuration for the interconnection between the Québec Eastern Townships and New England. Moreover, members of the department participated in the coordination work of a Hydro-Québec committee set up to study the biological effects of electrical equipment.

The past 12 months also witnessed the implementation of techniques designed to upgrade the data acquisition and processing system for partial-discharge measurements on power transformers and fault detection methods used during impulse tests on this type of transformer.

Finally, the activities in the high-voltage laboratory have given rise to interesting developments, such as a new design of SF_6-insulated 1000-kV AC fibreglass bushing, and new and original test techniques. Other major work included DC pollution tests at 400 kV for the City of Los Angeles as well as dielectric tests on a 140-kV 3600-A thyristor valve for the Châteauguay interconnection substation linking the Hydro-Québec power system to that of the New York Power Authority.

The high-voltage laboratory.

Electrical Performance of Transmission Lines

Manager
P. Sarma Maruvada

In accordance with its mandate, the Electrical Performance of Transmission Lines group plans and carries out the research, development, demonstration and consulting activities related to the selection and coordination of the electrical parameters of new AC and DC transmission line designs. It also contributes to the optimization of existing transmission lines and to the evaluation of the environmental impact of power system facilities.

Over the last 12 months, the group has pursued its studies on the electrical design of the ± 450-kV DC line to link Québec's Eastern Townships to New England. Tests to be performed over a one-year period should provide a statistical description of the impact of this line on the local environment and the data needed to establish new DC test techniques for the laboratory and field testing of insulators. The

Design studies were performed on IREQ's experimental line in connection with the future ±450-kV line between the Eastern Townships and New England.

laboratory test facilities for evaluating the performance of polluted insulators are being upgraded to allow simultaneous testing in all three fog chambers (clean or salt fog). A study has also been made to determine the influence of the various parameters of an AC power supply on the flashover voltage of polluted insulators.

Work on external insulation in 1983 included a study for CEA to determine the clearances required for electric railway systems operating at 50 kV. This called for rod-plane air breakdown tests with different waveforms over a wide range of atmospheric conditions covering tunnel as well as outdoor environments.

Within the framework of a project on the electrical performance of HV lines at high altitudes, a study was also made of the dielectric strength of a rod-plane configuration in relation to atmospheric pressure and humidity. The tests were performed in a test tank equipped with controls for regulating the pressure and humidity of the air inside.

The year's activities related to corona and electric field effects cover a broad spectrum. Measurements of the ion density caused by DC corona were made in the high-voltage laboratory and, also, under the experimental line in Varennes. At the request of Hydro-Québec's Environmental Planning department, the group carried out an evaluation of corona effects to provide the utility with the supporting data needed for the public hearings held on its planned ± 450-kV DC line. In addition, a fibre-optic transmission system was developed for use in a joint study with the Royal Victoria Hospital in an attempt to limit the effects of electrical burns. The group also participated in the activities of a Hydro-Québec committee created to look into the biological effects of electrical apparatus.

Publications and Technical Reports (see insert)
CP 4, 5, 41, 66, 75, 76, 91, 96, 97, 114, 115
PU 29
TR 8, 25, 26, 102, 103, 105, 109

Internal Insulation

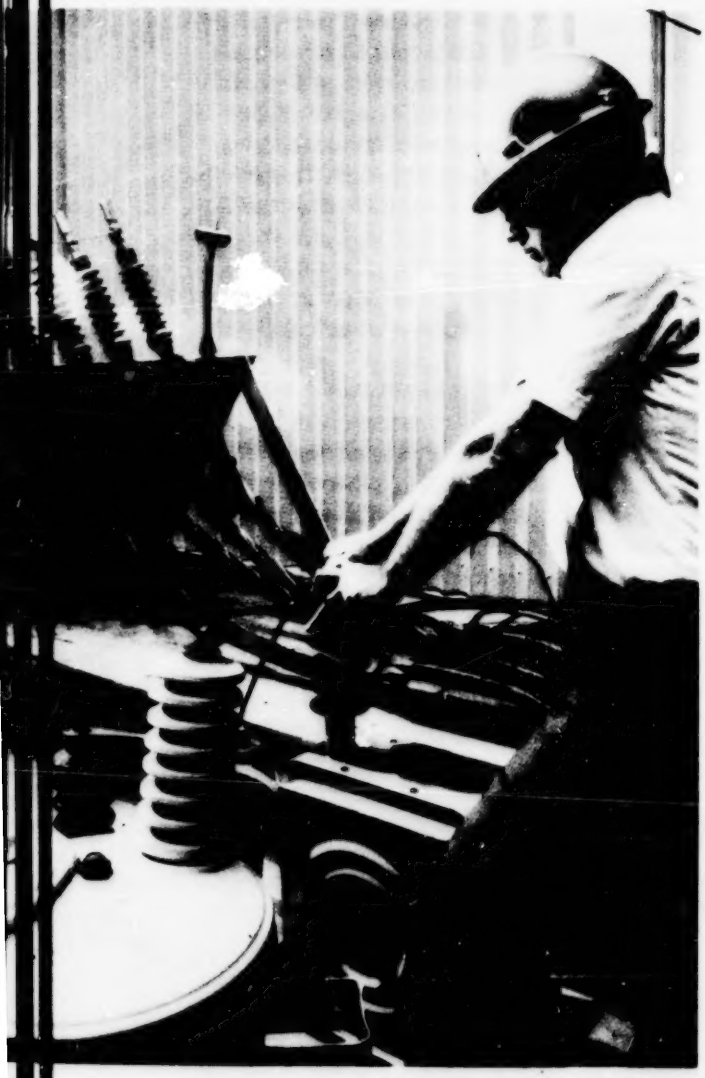
Manager
N. Giao Trinh

The terms of reference of the Internal Insulation group are to carry out research, development and demonstration activities related to the characteristics of HV power transmission and distribution equipment. In pursuit of these objectives, the group focuses its studies on the three main categories of insulation, namely: gaseous (such as SF_6), oil and solid insulation.

The work on SF_6 in 1983 was oriented largely toward the low-temperature performance of gas-insulated equipment. This involved, in particular, an evaluation of SF_6-N_2 mixtures as a practical solution to the low-temperature problem. Work in progress comprises a study of the fundamental parameters of the gases involved and different mixtures of these gases, which should provide a basis for more appropriate selection of gases for specific applications. The increasing use of gas-insulated equipment at Hydro-Québec raises other problems, especially with regard to transient rise in ground potential in gas-insulated substations and the protection of gas-insulated equipment against overvoltages. Both these aspects are now under investigation, the first at the request of Hydro-Québec's Equipment Management department, the second in a study for CEA, which deals more specifically with the characterization of the dielectric strength of gas-insulated busbars subjected to steep-front impulses.

In the field of oil insulation, the focus of attention in 1983 was contamination in the form of solid particles. This was the subject of a study performed in collaboration with the Equipment Management department to characterize the particles in the oil of Hydro-Québec transformers. Another interest is the long-term behavior of transformer insulation and, in a study for the utility and CEA, work has been undertaken to assess the dielectric strength and short-circuit withstand capability of a number of power transformers removed from the system after 17 to 25 years of service. Test results show a slight decrease in the dielectric strength of the transformers under study but a good resistance to short-circuit tests. Aging of the insulation of instrument transformers is another subject under study and, in conjunction with Hydro-Québec's Maisonneuve Region and Equipment Management department, the group is engaged in determining the causes of the large amounts of dissolved gas in selected units.

HV cable-related studies comprised an investigation for CEA on the aging of distribution cables exposed to oscillatory overvoltages generated during capacitor switching operations. These investigations were carried out in the high-voltage laboratory, together with long-term tests on 15-kV and 25-kV cables and related hard-



Aging tests on distribution cables exposed to oscillatory switching surges.

ware. The group is also involved in research on HV cable fault detection and location and in the development of a method to detect whether or not out-of-service equipment is energized, for Hydro-Québec's Apparatus department.

In addition to the activities just described, the group has frequently contributed its expertise to Hydro-Québec for various studies on instrument transformers. And it has carried out evaluations for other Québec and Canadian corporations, including CCV (consultants in Venezuela) in order to assess 4000-MCM conductors for 800-kV substations operated by *EDELCA*, and Maritime Electric Co. to analyze the causes of faults on their voltage transformers.

A good many of these projects will continue in 1984, although the emphasis is expected to be on the aging of insulation systems with a view to obtaining useful data on the in-service performance of power equipment such as current transformers, metering devices and capacitive dividers.

Publications and Technical Reports (see insert)
CP 100, 104, 133, 134, 135
PU 14, 36

Line Mechanics and Vibration

Manager
Claude Hardy

The Line Mechanics and Vibration group carries out research, studies, testing and consultancy in the fields of structural mechanics, vibration dynamics and, in particular, the dynamic performance of overhead conductors in response to the wind. The personnel of this group are devoted to general research work, experimental activities in the mechanical and vibration laboratories in Varennes and testing on the Magdalen Islands experimental line.

The last 12 months saw the completion of a study of the method of applying standing waves to the measurement of the self-damping factors of overhead cables and conductors in a test span. This study comprised a detailed analysis of the power losses at the ends of the span and a quantitative evaluation of interference due to aerodynamic damping and coupling of longitudinal and transverse waves. Before the year-end, the technique was applied for measuring the self-damping of a steel overhead ground wire.

Work continued on a study for CEA on the eolian wind power imparted to single conductors. Now that the second stage of the experimental measurements has been completed, the data is being analyzed using random-excitation models. In another contract for CEA, work is in progress to demonstrate the feasibility of spectral- and modal-analysis techniques for determining the characteristics (stiffness, inertia and damping) of dampers and spacer-dampers used for reducing eolian vibration and subspan oscillations of overhead conductors. Numerical simulation work on the aeroelastic stability of conductor bundles was also pursued.

Field tests on the eolian-vibration computation model revealed that without accurate data on the conductor's self-damping characteristics, such calculations are not fully reliable. Meanwhile, the group has resumed its calculation of electrodynamic stresses in the various components of conventional and low-profile busbar structures under short-circuit conditions. The aim is to take account of rapid reclosing on fault and complex structural components such as multiconductor busbars, expansion joints and elastic foundations.

Insulators are another interest and many studies and tests have been carried out at the Varennes laboratories. Among others, mention can be made of an investigation into the time to failure under stress of synthetic insulators, some of which had undergone 25 000 hours of testing by the end of the year. In addition, electromechanical tests have been performed on high-strength insulators, as well as cantilever strength tests on synthetic post insulators and combined tensile, bending and torsional tests on porcelain cap-and-pin insulators.

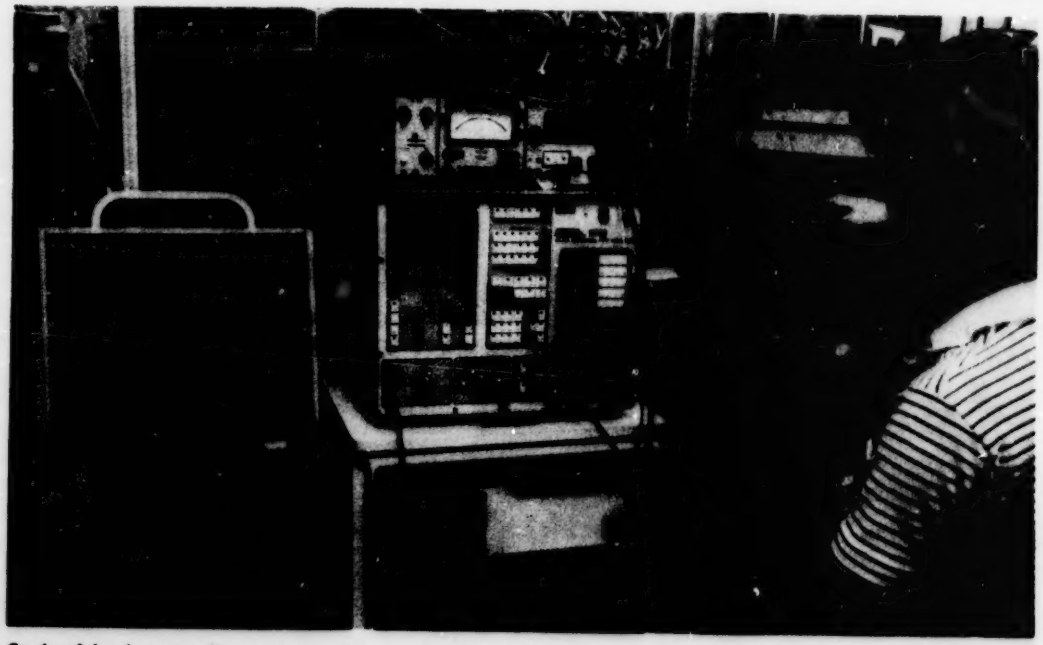
Mechanical tests were carried out over the last 12 months to determine the breaking limit both of Alcan 1714-MCM conductors and of the damaged guy wires of transmission towers when they are equipped with the preformed armor rods used for repair work. Other structural aspects studied include the tensile load-elongation curve of the strands of overhead ground wires, creep of the dead-end sleeves of jumper assemblies used for 4000-MCM conductors, the stiffness of Belleville washers before and after a pulsating load, and the deformation of a trans-

former-coil lifting device. To evaluate the breaking strength of stranded conductors as a function of the strength of their individual strands, the group is working on a resin socketing method which would ensure that ruptures occur in the free section of conductor lengths. It also carried out measurements of the behavior of a nutcracker type of rubber-lined spacer clamp under longitudinal slipping and tightening conditions, as well as the slip resistance of spacer attachments comprising preformed helical armor rods.

In another area, two different types of remote-control system for distribution feeder automation were subjected to environmental and vibration tests for quality evaluation purposes. Quality evaluation was also the aim of the studies performed on prototypes of an electronic meter-reading device which involved free-fall, vibration and drop-and-topple tests. The laboratory personnel also responded to requests from Hydro-Québec's Gentilly 2 nuclear power station to determine the natural frequencies of the steam lines and a motor-pump.

Work on the Magdalen Islands test line included a study for *EDELCA* to determine the efficiency of two spacer-damper systems in attenuating eolian vibrations and subspan oscillations. The test set-up, which comprises four 1300-MCM ACAR conductors with a 450-mm spacing, was used for a similar evaluation of the Hydro-Québec spacer system, while in the fall of 1983 work began on the same type of study for *DAMP* in response to a request from *ENDESA*. Finally, experimental measurements were completed to evaluate the performance of a new twin-spacer system.

Publications and Technical Reports (see insert)
CP 66, 68, 136
PU 20, 50
TR 9, 10, 44



Study of the dynamic characteristics of spacers for line conductors.

High-Voltage Measuring and Test Techniques

Leader
Ryszard Malewski

Specializing in the development of advanced HV measuring and test techniques, this team is particularly involved in the design and construction of original devices that could expedite or automate HV testing.

In 1983, the HV laboratory's 15-MVA source was employed to develop a synthetic-test technique for measuring iron losses in large power transformers of approximately 500 MVA. This new technique is based on the use of a 100-μF (18-Mvar) capacitor bank. It allows the transformer under test to draw high currents when energized at 115% of its rated voltage level and a smooth test-voltage waveform to be maintained up to this level for transformer ratings of up to 560 MVA. Furthermore, by careful selection of the test circuit components, it is possible to eliminate the problem of ferroresonance, which could appear in the circuit as a result of nonlinearity.

The team successfully put into service a new digital recorder for measuring the transients that occur during impulse tests on power transformers. This device gives a far better resolution than conventional analog oscilloscopes. Work is now under way to develop specialized signal-processing programs.

In another area, an automatic HV insulation monitoring system for in-service power transformers has been modified so as to distinguish internal partial discharges from external noise sources.

One notable achievement in 1983 was the design, construction and testing of a more sophisticated version of the leakage-current detector used for insulator pollution tests in the HV laboratory. The new model has a better performance than the present prototype, especially for the processing of results, and it also allows the comparison of results obtained from several tests.

It is also worth pointing out that the digital monitoring system developed at IREQ last year for studying polluted insulators under natural conditions was installed in two locations in the Montreal area in 1983 and, with several months of operation, has proven satisfactory.

Other activities of note include the refinement of a real-time digitization device for the partial-discharge data acquisition and processing system, especially for discharges measured on three-phase transformers during tests in the HV laboratory. These discharges are characterized by their apparent charge, their polarity and the phase of the equipment on which they appear. The digital-data format is compatible with the acquisition unit, which is designed to multiplex signals from the various measuring channels connected to the transformer bushings.

Finally, a study was completed for CEA to investigate the electrical characteristics of galvanized steel conductors with a view to determining the AC/DC resistance ratio in relation to the current and temperature.

Publications and Technical Reports (see insert)
CP 85, 86, 87, 88, 89, 117, 139, 140, 141
PU 27, 28
TR 68, 90
AD 18

High-Voltage Laboratory

Manager
David Train

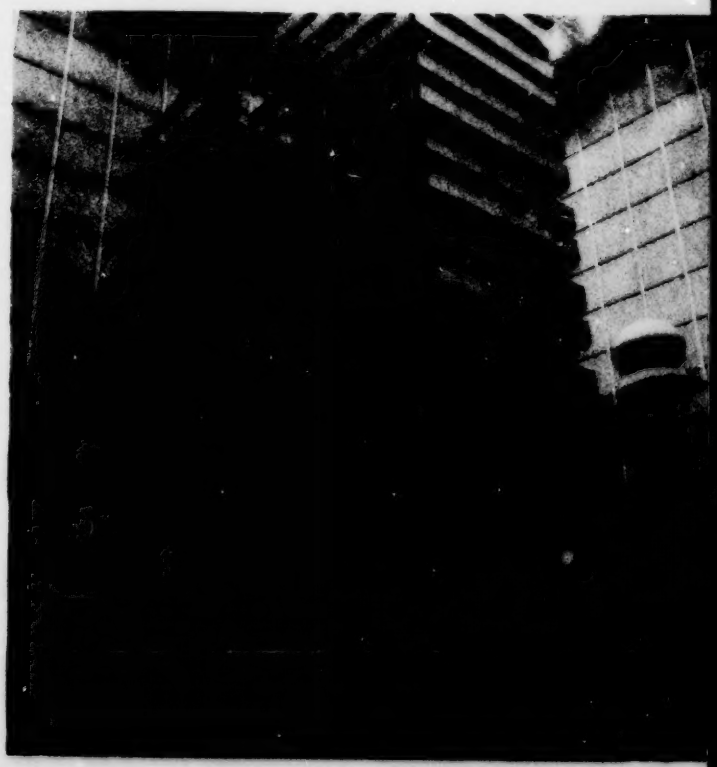
In the past year, the high-voltage laboratory recorded 2049 test periods[1] in the execution of 161 contracts. There was increased activity in high-voltage DC testing such as pollution tests at 400 kV DC on suspension insulators; dielectric tests on a 140-kV, 3600-A thyristor valve; dielectric tests at up to 750 kV DC on disconnecting switches; and corona studies on bundled conductors for a ± 450-kV transmission line.

Other significant activities in 1983 included the design, manufacture and testing of a 1-MV_{rms} bushing having a fibreglass shell and insulated with SF_6. Two such bushings are to be installed in the SF_6 test cell with a view to eliminating the explosion hazard which exists with the present porcelain-shell SF_6 bushings, while a third will be assembled with a porcelain-shell oil-impregnated-paper bushing and an SF_6 tank in order to provide a special hybrid bushing arrangement to supply the large pollution chamber.

Tests performed:

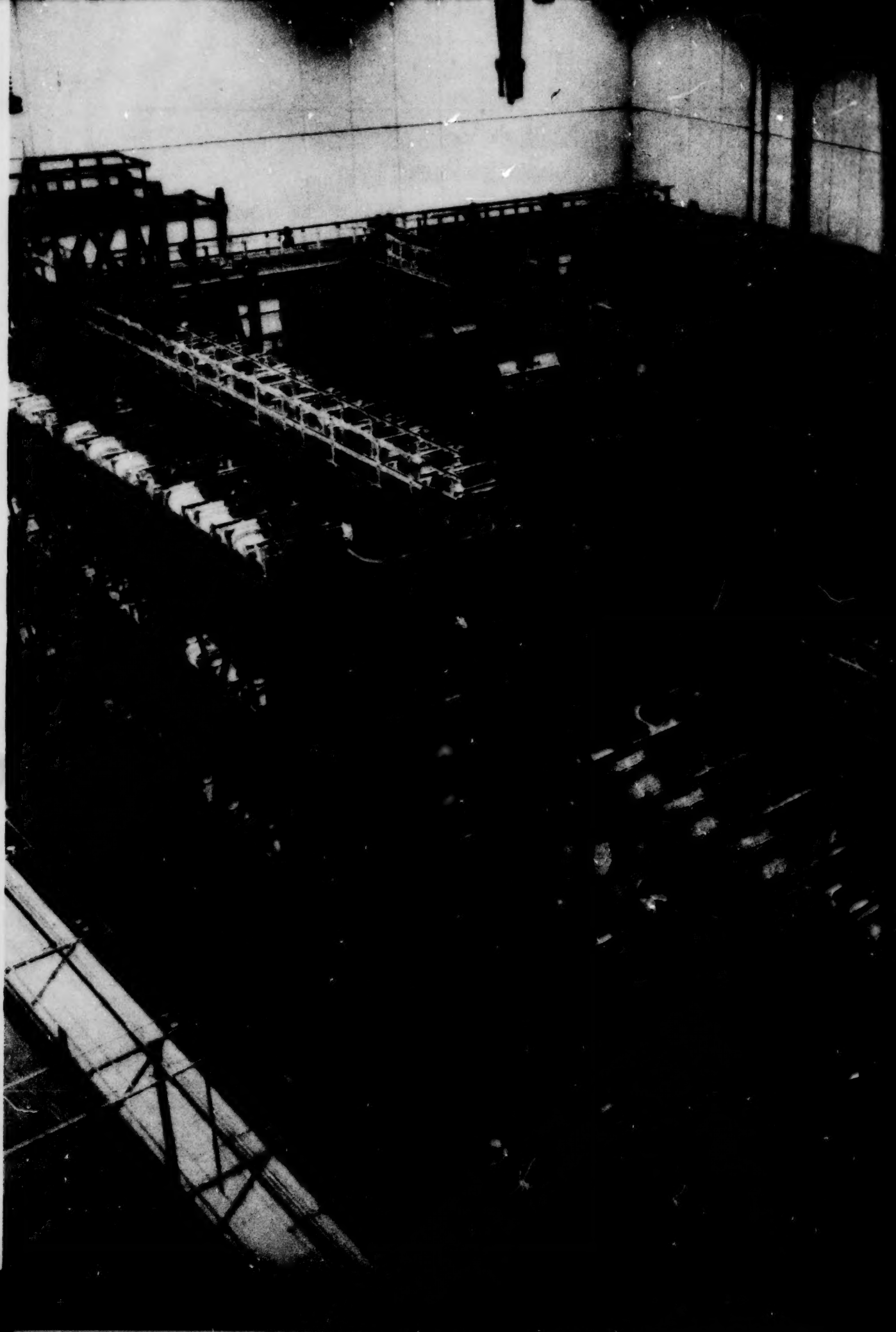
- Type and routine tests on power transformers
- Type and routine tests on shunt reactors
- Load cycle tests on cables
- High-voltage AC and DC tests
- Artificial-rain tests
- Switching-impulse tests
- Lightning impulse and chopped-wave tests
- RIV (radio influence voltage) measurements
- Partial-discharge measurements
- Capacitance and loss-angle (tg δ) measurements
- Ultrasonic detection
- AC and DC tests on contaminated insulators
- DC corona tests on bundled conductors on the experimental line
- Measurement of AC and DC resistance of power cables.

Publications and Technical Reports (see insert)
CP 131
PU 49
TR 88



Dielectric tests on a 140-kV, 3600-A thyristor valve.

1. A test period equals seven hours.



ELECTRICAL EQUIPMENT

Director
Gilles A. Bertl

The Electrical Equipment department has as its mandate to forecast, plan, carry out and assess the Institute's research, development, demonstration, testing and consultation activities related to the effects of current and power on electrical equipment.

When the synthetic test circuit went into service in 1983, another important phase in the construction and commissioning of the laboratory's major facilities was completed. A full range of tests on connection and conversion equipment can now be offered to clients.

In effect,with the synthetic test circuit, the department is now thoroughly equipped to undertake studies aimed at enhancing power system reliability and improving the quality of customer service. Research and testing on surge arresters and 735-kV circuit breakers intended for the James Bay transmission system have already yielded valuable technical data for solving future problems. The synthetic test circuit was an indispensable tool for obtaining such data, allowing test levels never attained before. Further work on system reliability and service quality in 1983 included a study of the aging and degradation mechanisms of DC valves, static compensators, transformers and busbars. Moreover new test methods have been developed for such equipment.

The department has kept pace with Hydro-Québec's latest priorities and has accordingly decided to devote more than one quarter of its resources to the optimization of existing installations. Distribution equipment in particular will be its major concern, with the emphasis largely on equipment protection and personnel safety.

While the department intends to continue marketing its expertise abroad, as now in Brazil, Mexico and Peru, it is also working on technological transfers to Québec industries. In addition to completing the development of the disconnector-blade position indicating system, in 1983 it joined forces with Québec industrialists to develop totally new generations of circuit breakers and industrial steam boilers.

The high-power laboratory's synthetic-test circuit went into operation in 1983.

Electrical Energy Conversion Equipment

Manager
Louis Masson

Responsible for research, development, demonstration and consultancy work related to the effects of electric currents in energy conversion equipment, this group performs a wide range of studies from power system apparatus in general to more specialized areas such as magnetic circuits, grounding, safety of personnel, power electronics and electrodynamic loads.

The group's achievements in 1983 can therefore be discerned in many areas. In the framework of the *Tokamak de Varennes* project, for example, the specifications for the power supplies needed for the magnetic confinement machine were finalized and, once the bids have been assessed, work will begin on installing the equipment.

A study was initiated in collaboration with Hydro-Québec and a Québec turbine manufacturer to examine the coupling of a low-speed hydraulic micromachine to a power system by means of an electronic converter.

In the field of substation equipment, various studies were performed for Hydro-Québec on such matters as electrical equipment characteristics, transformer-winding displacement detection, DC current effects on converter station transformers, grounding system insulation in DC substations, and valve testing for HV converter substations and static compensators. Also for Hydro-Québec, work was pursued on an autoregulated variable inductor designed to act as a reactive-power compensator.

For EPRI, meanwhile, a study was completed on suspected equipment problems in DC substations operating at over 600 kV. Other projects related to HV voltage and current trans-

Development of a variable reactor.

formers were undertaken for both Hydro-Québec and ASEA Inc. A hot-spot temperature detector for power transformers has been tested and an ultrasonic blade-position monitoring system for disconnecting switches has been developed. Finally, work began on a study of techniques for detecting accidental three-phase line grounding prior to energization.

With regard to distribution-related activities over the past 12 months, the group carried out several research projects for Hydro-Québec and CEA with a view to determining and possibly correcting the conditions that could be hazardous to human beings, such as ground potential rise in the vicinity of bucket trucks, induced and conducted voltages in underground cable duct banks, and voltages induced by capacitive coupling in the ungrounded neutral conductors of no-load transformer banks.

Concurrently with development work on a variable reactor, the group pursued its development of an autoregulating reactor-transformer to operate at voltages matching those of power supplies tapped from the overhead ground wire on EHV transmission lines.

Various projects were also undertaken on the possibilities of industrial applications of electricity. One of the projects involved the development of 25-kV steam boilers, while another concerned the interaction of arc furnaces with electrical power systems; the latter was at the request of *SIDBEC* and *Electroperu*. In addition, the group carried out a number of preliminary studies on electric-propulsion vehicles and it undertook the development of a traction system for electric or hybrid vehicles.

Finally in 1983, studies were conducted with a view to optimizing the equipment in IREQ's test laboratories. Transformers and measuring systems for the new facilities, capacitor bank protection and the installation of an HV cable duct bank for test purposes were among the topics investigated.

Publications and Technical Reports (see insert)
CP 2, 127, 134
TR 1, 45, 46, 47, 48 ,49, 64
AD 20

Switchgear

Manager
Guy St-Jean

Synthetic tests on 735-kV air-blast circuit breakers.

A ten-year effort devoted to the design and construction of a synthetic-test power source for switchgear research, development and testing culminated last July with the commissioning of this unique facility in the high-power laboratory. It is now operating at full capacity.

Two patents have been taken out on the test installation, which is original from the standpoint of both its structure and the electrical design. Its switching system is laser-triggered while all operations are controlled by computer. Comprising over 4000 high-voltage (30 kV to 360 kV) components, the test source allows full-scale simulation of the stresses imposed by EHV power systems on switching or protection equipment. This facility thus completes the range of test techniques offered by the high-power laboratory.

It is worth mentioning that over 300 synthetic tests have already been performed for Hydro-Québec using this new source in a comparative study of two types of 735-kV air-blast circuit breakers intended for the James Bay transmission system. Another aspect of these breakers that was investigated was their performance when subjected to crest voltages of ≈2000 kV following out-of-phase interruption of a 5-kA current.

The group also worked on a test project to determine the quality of "sacrificial" zinc-oxide arresters which limit 60-Hz overvoltages consequent upon load-shedding operations. The aim of this project is to verify that the protection provided by various types of surge arrester will meet Hydro-Québec's requirements for the James Bay system.

In the field of distribution equipment, work was completed on a project for CEA aimed at determining the Canadian industry's needs as regards submersible fuses. A survey revealed that this type of fuse is in great demand and that there are a number of shortcomings in the range of devices presently available. In another study under way for CEA, the group is investigating the industry's needs in relation to distribution surge arresters. Meanwhile a research project was recently initiated to accelerate Hydro-Québec acceptance of the cadmium ("Q") fuse design, which IREQ has developed in collaboration with Kearney. The latter is now manufacturing this fuse in Québec for the world market. The aim of the tests is to demonstrate the reliability of these fuses when exposed to simulated lightning strokes in the laboratory.

On-going research on short-circuit interruption tests is focused on the development of a method for predicting the failure level of the circuit breakers under test. This should significantly reduce the number of tests normally required as well as opening up a testing and development market for IREQ. Already, a mathematical model of breaker arcing has been developed for this purpose while work is in progress on the development of a post-arc conductivity measurement technique.

Publications and Technical Reports (see insert)
CP 3, 97, 111, 120
PU 43
TR 40, 41, 58, 59

High-Power Laboratory

Manager
Jean-Guy Pineault

During the past year, the high-power laboratory recorded 638 test periods.[1] Of these, 118 were in the medium-voltage test station, 110 in the high-voltage test station, 275 in the environmental chamber and the remaining 135 in the high-current and other test areas. One half of the test periods were for Hydro-Québec while the other half were split fairly evenly between outside clients and the Institute itself.

Two world firsts were achieved in 1983. One of these involved short-circuit tests on a Trench reactor with a high inductance, which called for a two-phase power source of over 6300 MVA. This inductor is a component of the rectified-current filter for the DC sending-end substation of a submarine cable link between England and France. The second breakthrough was to attain crest voltages of 2000 kV during out-of-phase switching tests on 735-kV air-blast circuit breakers. The latter tests formed part of a vast program of investigation on the interrupting-capacity limits of some of Hydro-Québec's EHV circuit breakers.

These tests were the first to be performed after the synthetic-test circuit had gone into operation in the high-power laboratory. Commissioning went very smoothly according to a short, clearly defined schedule. The performances obtained so far have had a positive effect on the number of contracts for synthetic testing in this laboratory and contributed to a marked increase in its popularity.

Other novel tests were undertaken in 1983 in the high-power laboratory, including:

- temperature-rise tests on high-impedance medium-voltage inductors (100 to 400 Ω), with fibre-optic transmission of temperature signals to ground level
- interrupting tests on 300-V DC current-limiting fuses
- hot thyristor firing tests (water temperature 95°C) with and without valve blocking, using a 4000-μF oscillating circuit
- no-load line disconnection tests on one chamber of a 735-kV circuit breaker, with breaking currents reaching values of up to 2000 A and the synthetic-test-circuit capacitors used to maximum capacity
- measurements using coaxial shunts (high-voltage part) with fibre-optic signal transmission.

1. A test period lasts seven hours.

Control room for the new synthetic-test circuit.

The laboratory underwent major structural modifications in 1983 while an underground-duct bank was built for performance tests on 315-kV cable, which are scheduled to begin in the new year. Finally the laboratory's technical personnel pursued its studies of new test techniques, diagnostic and measuring tools, and testing facilities.

Publications and Technical Reports (see insert)
CP 110
TR 34, 35, 73, 74, 80, 87, 98, 99

SYSTEMS ENGINEERING

Director
Raymond Pronovost

In an aim to minimize the utility's capital and operating costs and to improve the quality of customer service, this department is engaged in planning, carrying out and evaluating research, development, demonstration and study activities related to power system analysis and automation. It also undertakes consultation for Hydro-Québec and outside clients.

Four research groups share the various tasks involved in the pursuit of these objectives. One is responsible for the development of planning and operating methods for power generation, transmission and distribution systems and, also, for the application of such methods for system protection and parameter identification. Another group develops analog power-system simulation techniques and performs a variety of system studies for Hydro-Québec and outside clients. The studies undertaken by the third group cover electronic control, measuring and communication techniques in a search for solutions to power system automation problems. The last group is responsible for developing and applying expertise in real-time digital data acquisition and processing systems.

The year's activities comprised further work in fields already established and new projects in different domains. Achievements of note in the first category include the implementation of a set of power system analysis programs on an Apollo microcomputer, which endows the Institute with a relatively inexpensive micro-simulator for studying medium-size power systems. Another project involved the development of various microprocessor-based automatic controls for such apparatus as reclosing circuit-breakers, a universal reclosing device, voltage regulators for distribution substations, distance relays for transmission system protection, etc., all of which were for external clients. System studies were also performed for Hydro-Québec on the James Bay transmission system and on DC interconnection substations as well as for manufacturers and clients from abroad. Various data acquisition and processing programs were developed and incorporated along with text and graphic editing software with a view to optimizing the utilization of IREQ's simulators and test laboratories.

The new activities include the development of a robotized system for repair work on hydraulic turbine blades damaged by cavitation, and the design of tools for evaluating the condition of heavy apparatus for preventive-maintenance scheduling purposes. One example of such tools is the air-gap measuring system for rotating machines.

In addition, many of the research efforts of the last few years found commercial applications in 1983, thus providing support for Hydro-Québec International in its marketing activities as well as increasing the department's contribution to ensuring greater profits for IREQ. Finally, technological transfers have fostered participation in Québec's industrial development.

Development of a robotized gouging system for turbine maintenance.

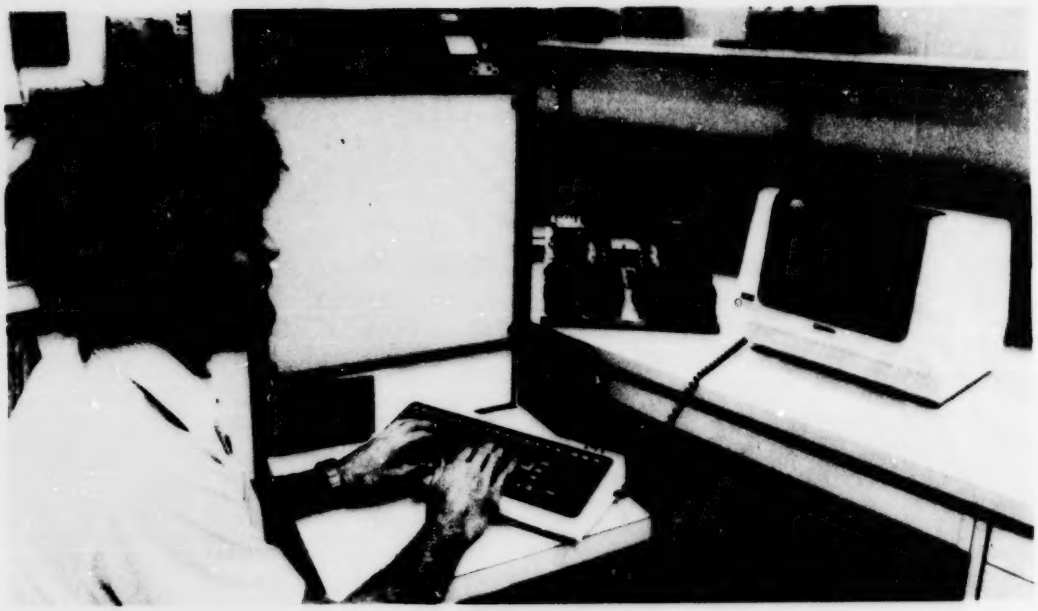
Power System Analysis and Production Planning

Manager
Yvan Robichaud

As in past years, the group's activities in 1983 were largely devoted to production planning. Thus research was pursued on the development of nonlinear deterministic generation scheduling models, the approaches under investigation being based on second-order graph optimization methods. A major effort was also devoted to upgrading programs already developed for Hydro-Québec's Power System Planning department. The CYRUS model for river management has now been expanded to cover the case of a number of valleys in parallel. Meanwhile NUMA, the deterministic production scheduling model, has been further improved and a new formulation of the objective function has been proposed to deal with cases having a complex market structure. Another study was performed for the utility's Equipment Planning department to develop a set of programs related to the choice of equipment, while a study for CEA involved the development of an analytical method for assessing the economic impact of adding wind power generators to a conventional utility system. The finishing touches were also put to a computer-based system of evaluating distribution system reliability; the system has now been installed for testing in the Mauricie region of Québec.

The set of power system analysis programs designed to meet Hydro-Québec requirements now covers power flow, contingency analysis, short-circuit-current calculation, transient stability and one-line network diagrams. During the past year, attention focused on optimization of the existing software package and on the addition of new component models (protection relays, DC links, induction motors at the Gentilly nuclear plant) in answer to requests from the utility's Equipment Planning and Production Scheduling departments.

IREQ's digital power system simulator was used for a wide range of internal projects as well as for firms of consultants in the Montreal area. The major achievements in 1983 included the development of a digital power system micro-simulator and participation in DC interconnection studies and network islanding. Furthermore, in collaboration with Hydro-Québec International, the group signed contracts with organizations in India and Colombia for the transfer of technology and power system analysis programs and offered its services in several other countries.



Development of an automatic control for voltage regulation in substations.

In the area of power system parameter identification, work was initiated on the design of a new generation of multibus data acquisition and processing systems compatible with IEEE standard 796, which should be sufficiently flexible to meet any specific need.

At the request of CEA, specifications were drawn up in cooperation with Ontario Hydro to define a system for identification of load characteristics. Another CEA project, this one involving a voltage regulation device for distribution substations, is well under way. The past few months were devoted to the implementation of application and self-diagnostic programs. The system will be installed in a Hydro-Québec substation, while the contract calls for two substations in New Brunswick to be similarly equipped in the near future. It should be mentioned, too, that a prototype distance-relay protection device based on the use of microprocessors has been successfully installed in the Boucherville substation; tests are scheduled to continue during the next 12 months. At Hydro-Québec's Gentilly 2 nuclear power plant, modifications were made to the data acquisition system used for the parameter identification of the motors of hydraulic circulation pumps. Finally, tests relating to the aging of distribution equipment were performed for CEA in a number of Hydro-Québec and Ontario Hydro substations.

Publications and Technical Reports (see insert)
CP 21, 35, 44, 45, 65, 74, 118, 119, 129, 137
PU 19, 33, 48
TR 2, 7, 17, 27, 52, 63, 73, 78, 85, 101, 112, 113
AD 14, 15

System Studies and Simulation

Manager
Chandra Krishnayya

Behavior of the Hydro-Québec/NEPOOL interconnection is studied on the HVDC simulator.

In the pursuit of its terms of reference, this group carries out research, development, demonstration and consulting activities related to the control and transient behavior of power systems. It is also responsible for promoting the use of the AC and DC power system simulators developed at IREQ. With such a wide scope of activities, the achievements over the last 12 months show an understandable degree of diversity.

The AC system simulator was used for a study of the various strategies and options associated with the islanding of Hydro-Québec's 735-kV grid following a general power failure. A number of solutions based on the use of series compensators or treble-tripler type saturable reactors have been analyzed.

In collaboration with MONENCO, two studies were performed for TransAlta Utilities. The first was to evaluate the performance and detailed design of a 500-MVA static compensator to be incorporated into the Albertan company's 240-kV power system; this involved the optimization of the controls and an assessment of the electrical stresses on each power component. The second study, on the installation of a double-circuit 500-kV line, dealt with transient overvoltages and secondary-arc currents. Canadian General Electric also made use of the Institute's AC power system simulator to improve the control system for its static compensators in the Nemiskau and Albanel substations forming part of the James Bay transmission system.

Meanwhile the DC simulator was used to study the performance of the proposed interconnection between Hydro-Québec and New England Power Pool (NEPOOL). In another study, at the request of Brown Boveri, tests were performed to evaluate the performance of the control systems for the Châteauguay substation, the point of interconnection between the Hydro-Québec power system and that of the State of New York.

Two research contracts were signed with CEA, one to evaluate the performance of metal-oxide surge arresters and the related stresses under AC transmission conditions, the other to compare the dynamic behavior of two wind power generator configurations—one with, the other without, a synchronous machine. Another two projects were undertaken with EPRI. The first consisted in preparing guidelines for DC transmission system planners, the second in implementing multiterminal models in EPRI's power flow and stability programs.

In a different context, the group has also developed a system for the asynchronous interconnection of electric grids based on the use of variable-reactance devices comprising capacitors, inductors and thyristor valves. AC simulator tests on this system are scheduled for 1984. It should also be mentioned that the group is currently establishing a method for testing thyristor valves used in static compensators. Concurrently with these activities, marked progress has been made in the area of equivalent networks, which can also be applied for power system simulation as well as for digital simulators. The simulation of wind energy conversion systems and induction machines continues to interest the group and, too, the validation of multiterminal DC system models in IREQ's stability program.

Among the major achievements of 1983 in the construction of special simulator components, mention should be made of a network interconnection and measurement system, a microprocessor-based local control system for circuit breakers, and four Siemens controls for converter models. Finally in this field, a data management program has been developed and put into operation for automating the process of modifying power system configurations.

This report of the year's activities would not be complete without a word on the group's active participation in the work of various utility committees on transmission systems. It has also responded to requests for evaluations and consultations in relation to the approval of static compensators for Nemiskau and Albanel, the evaluation of bids for the Des Cantons interconnection project (with NEPOOL), and the construction of the Châteauguay DC project. In collaboration with the University of Wisconsin, the group gave a course on DC system simulation and analysis to a group of engineers from seven different countries.

Publications and Technical Reports (see insert)
CP 19, 20, 46, 48, 49, 61
PU 5, 6, 26
TR 11, 13, 28, 29, 30, 67, 108, 111

Automatic Control, Measurement and Communication

Manager
René Blais

The year 1983 saw the completion of several projects. A feeder telecommand system was put into operation, for example, while a number of automatic controls for different types of equipment were developed, including an electronic control for reclosing circuit-breakers and for various multi-shut reclosing controllers. The two latter projects, undertaken in collaboration with Merlin Gerin and *SNÉMO* respectively, mark an important turning point in terms of marketing.

Significant progress was made in the development of an ice detector, particularly from the point of view of reliability. The next stage in this project will consist in increasing the degree of automation and in incorporating the device in a weather station. Work has also begun on a feeder protection project which should gather momentum next year; the aim here is to implement total feeder protection on microprocessors.

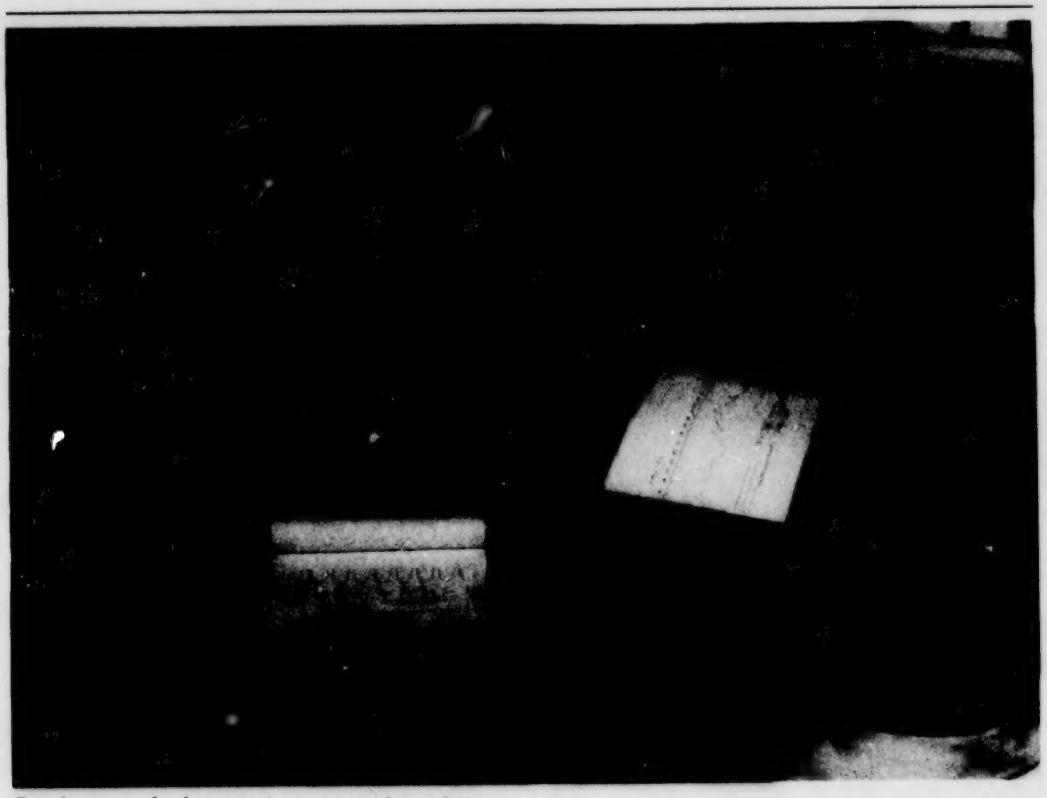
As far as measurement activities are concerned, the group designed and developed a compact, hence easily installed, sensor for measuring the air gap of an operational hydroelectric generator. It is now planned to add an electronic interface in order to achieve an integrated system of preventive diagnosis, with the air-gap measurements used as a basic parameter for the analysis. For the same purpose, work was pursued on the development of a data transmission system designed for installation on the rotor of the alternator; the DC field slip rings will serve as the transmission link and power source.

A project under way on power line proximity detectors for the protection of heavy-machine operators culminated in 1983 in the development of a reliable pre-production prototype. Meanwhile work was completed on the development of a device to protect welders from electric shocks. The group is hoping to market these two devices in the near future.

In addition, a project was initiated on techniques for examining the operating condition of electrical apparatus in service. The aim is to standardize the testing of such equipment by means of a minicomputer-based system and to build up a more comprehensive data base.

The relatively new activities in the area of robotics were pursued over the year, the main focus being on the development of a manipulator arm for the gouging of turbine blades damaged by erosive cavitation. The control unit for the lightweight gouging torch developed at IREQ for this purpose is nearing completion and the system should soon be ready for testing in a generating station. A study of multidimensional recognition and positioning systems will help to improve the accuracy of the surface-measurement system and, what is more, could also be used for tasks involving non-repetitive processes. Work of a more general nature in this field included a significant contribution to the definition of robot applications for EHV and distribution line maintenance; the robotics industry is expected to participate actively in this sphere in 1984.

With regard to communications, a fibre-optic data transmission link is now being installed between IREQ and the Boucherville substation, supported on the overhead ground wire in one section. This project is in collaboration with Hydro-Québec. Furthermore, an optical-fibre data acquisition and control loop has been installed at the same substation, while a simple fibre-optic telephone link has been developed for possible substation applications.



Development of a dynamic air-gap measuring system for rotating machines.

The group recently undertook a project for CEA to study the performance of optical-fibre control links between a high-voltage point and ground to determine their reliability. Meanwhile work continued on the development of a fibre-optic current transducer, with a prototype unit having a bandwidth of 100 kHz scheduled for completion early in 1984.

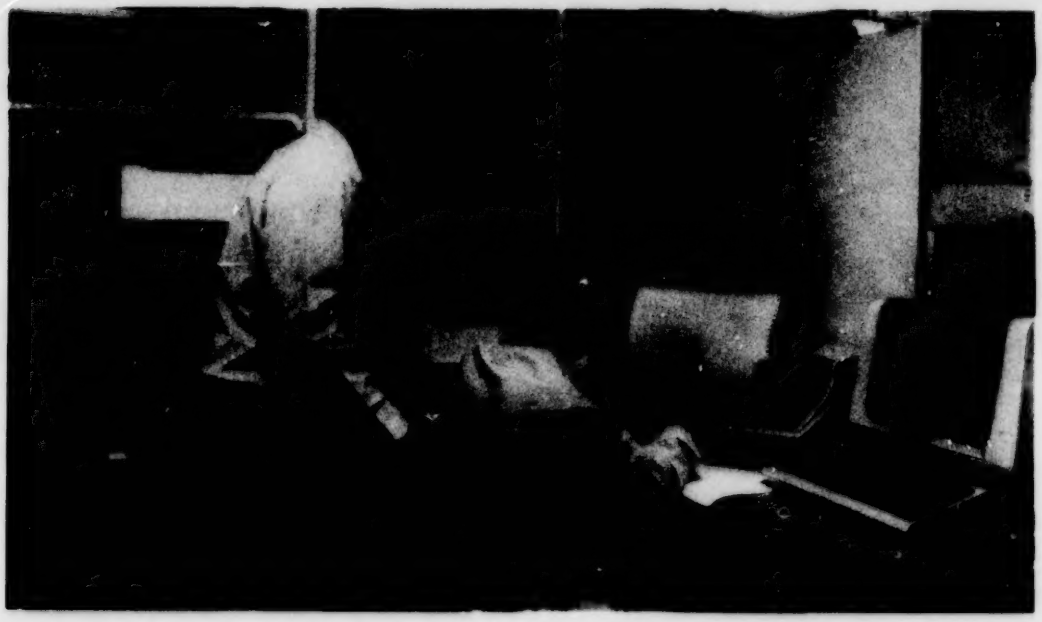
Research on precise time dissemination included the development and construction of a series of slave clocks, now in use on Hydro-Québec's power system, and the construction of an automatic back-up system for the master clock.

In a project concerning the measurement of the voltage phase angle of the Hydro-Québec system, a second-generation measuring unit incorporating a minicomputer was put into service in 1983. New transmitters will also provide measurements of the crest voltage of the three phases of the station busbar under observation. Hydro-Québec's system control centre and Automatic Control and Telecommunication division will thus be in possession of an even more powerful tool for rapidly obtaining all the information they need for monitoring and control. An improved version of the slave clock based on a rubidium standard and utilization of the IRIG-B system allow a synchronization accuracy of $\approx 10\ \mu s$ to be achieved at virtually any time.

Publications and Technical Reports (see insert)
CP 33, 34, 64, 99, 107, 109
PU 4
TR 36, 54, 72, 82, 83
AD 4, 12, 13

Data Acquisition and Processing Systems

Manager
Benoît Podesto



Microcomputer-based data acquisition and processing systems are under development.

In addition to its RD&D activities in the area of real-time data acquisition and processing and test process automation, this group is responsible for promoting the use of IREQ's computer centre. It also provides programming assistance to the various users. In 1983 the main thrust of its work was directed toward the development of microcomputer-based systems for various laboratory tests and of specialized packages to meet the wide range of research requirements by the Institute and its clients.

In conjunction with the members of Industrial Applications and Energy Conversion, the group developed a real-time data acquisition and control system for studying the ventilation in transformer vaults. This system can process 80 analog signals (temperature, thermal flux and electrical power readings) and comprises a specially designed parameter input-output program to facilitate man-machine dialogue. The advantage of using a computer here is that the air flow rate can be measured by the anemometric technique using heat pulses. The multiprocessing microcomputer is used for remote monitoring of tests and will also be applicable for simultaneous control of other test programs. The system is scheduled to go into operation in 1984.

Collaboration with the Metallurgy and Nuclear Technology group has led to the commissioning of a microcomputer-based control system for one of the test benches in the mechanical characterization laboratory. Computerized data acquisition and processing techniques offer an efficient aid in testing structural materials, as for example in testing ultimate breaking strength by the partial-discharge method and for measurement of resistance to fatigue. Moreover the same system has been successfully applied for Charpy impact tests.

In an attempt to integrate the many data acquisition and processing systems developed by IREQ over the years, the group has conceived and installed on the central computers, an interactive I/O control program employing a flexible and easy-to-use screen format generator. This not only ensures standardization of interactive communication techniques but also user-transparency of the terminals, thus affording easier maintenance of the application programs. Another advantage is that it significantly reduces the number of statements needed for the interactive aquisition-validation functions in all application programs involving man-machine interaction. Concurrently with these activities, the group is pursuing its study of data base management software that would allow standardization of the data structures used for the different data acquisition and processing systems now in operation at IREQ.

An important milestone was reached this year in the development of the TYRAN control and processing language for the various data formats used for laboratory tests at the Institute. The advantage of this interpretive language is that it allows mathematical programming in conversational mode as well as the incorporation of new tools. The graphic software CORE has also been implemented and studies are now under way on the possibility of using it for graphic editing and display.

IREQ's data processing specialists feel that the breakthrough of microcomputers into the world of science will lead to a new decentralized approach, with specific computer applications for laboratory measurements, data analysis and power system simulation. The research in 1984 will therefore be oriented towards upgrading the performance of the existing computer systems and initiating studies to assess the possibilities of system interconnection by means of high-speed links.

Publications and Technical Reports (see insert)
PU 16, 48
TR 59, 91, 92

ENERGY GENERATION and UTILIZATION

Director
Antoine Théorêt

This department's mandate is to plan, carry out and evaluate RD&D activities in the fields of energy generation, storage, utilization and conversion, and to investigate the materials involved in such applications. The scope is obviously extensive, ranging from energy generation (thermonuclear fusion, wind power generators, biomass, fuel cells, etc.) and storage (batteries, heat, hydrogen, etc.) to the rational utilization and conservation of energy in the residential, commercial and industrial sectors. In pursuit of the latter objective, the department is working mainly on the development of electrical technologies that could increase the application of electricity in industrial processes. The principal technologies under consideration are industrial heat pumps, plasma applications in industry, electrothermal or electromagnetic heating, conversion of electrical energy into fuels or raw materials (hydrogen, methanol, etc.) and, finally, electrochemical applications in the industrial sector (electrosynthesis, electrometallurgy, etc.).

The department is interested in all aspects of RD&D related to materials and systems of materials used in the generation, transmission, distribution and storage of energy. Its activities include chemical and metallurgical studies of nuclear and hydraulic equipment and research into insulating materials. This involves the development of processes, techniques and equipment as well as the study of phenomena related to the aging and degradation of such materials.

Six research groups are actively engaged in pursuing the objectives of this department, namely: Industrial Applications and Energy Conversion, Wind Turbines, Fusion, Hydrogen and Electrochemistry, Electrical Insulation, and Metallurgy and Nuclear Technology. In addition, a multidisciplinary team has recently been formed to look into industrial applications of plasmas, industrial heat pumps, and various heating techniques.

The highlights of 1983 included the installation of a 56-kW Darrieus-type wind turbine, the signing of a contract with *SNEA* in France for the predevelopment of polymer electrolyte batteries, the start of construction on the *Tokamak de Varennes* research facility, and the awarding of a contract to Marine Industries Ltd. to build the coils for the tokamak. A major contract has been signed with EPRI for the development of analytical characterization methods for studying materials used in extruded cables. In addition, a radioisotope laboratory has been set up and a new cobalt-based alloy has been developed which offers better cavitation resistance.

A plasma generator developed at IREQ.

Industrial Applications and Energy Conversion

Manager
Walter P. Schimmel

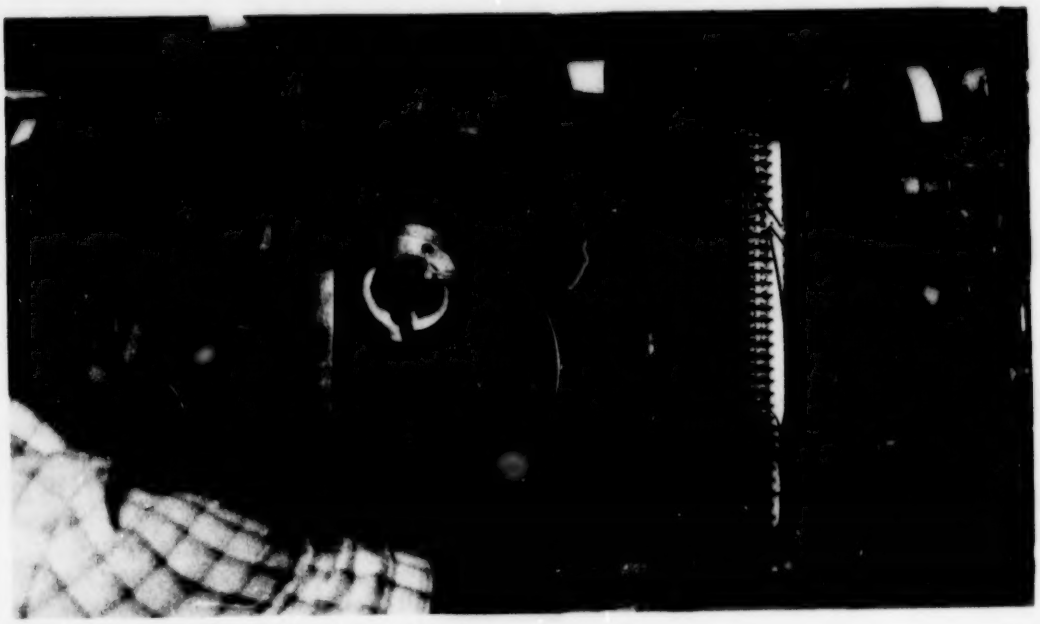
This group has two separate but complementary objectives, namely: to facilitate the development of those industrial processes which utilize electricity to produce heat, and to study the conversion of various energy forms in which the transfer and control of heat is important.

Under a project initiated in 1982 to evaluate the state of the art of RD&D of high-temperature, large-scale heat pumps, a comprehensive program has now been formulated with outside organizations. Work is under way towards an actual industrial installation involving a machine which will furnish ≈ 10 MW of thermal energy and whose coefficient of performance is expected to be greater than 4. The latter quantity is significant, since it represents a means of trading off the higher initial installation cost with savings realized through economy of operation when compared with other heaters, such as fossil fuel burners.

A closely related area which has permitted the group to develop its competence in heat pumps is the work on residential-scale equipment. A test bench installation has been completed and already used for transient-performance tests on an air/air as well as a water/air model to determine the effect of cycling. A preliminary test using a high-flux heat exchanger indicates that appreciable increases of heat transfer and decreases in required surface area are possible in future equipment designs.

A team of researchers was formed during the year for the specific purpose of generating demonstration projects involving industrial processes directly heated by electricity (by resistance, induction and conduction) as well as by electromagnetic radiation such as high-frequency, microwave and infrared radiation. Results of the studies so far will enable a multifaceted program to be formulated which should respond to the need for technical assistance at the commercialization level while affording opportunities for R&D contributions.

Under an ambitious program on industrial plasma torch applications, several pilot plant installations have been proposed. A program has been initiated involving not only members of the scientific community within Québec as well as researchers at IREQ and personnel of the Hydro-Québec marketing group but also manufacturers and users of plasma equipment. Construction has now begun on a laboratory facility for evaluation of the technical aspects of this technology.



Study of exchanger surfaces that enhance heat transfer in heat pumps.

Under a CEA contract on transformer cooling in remote transformer vaults, work was completed on the design and construction of an actual transformer installation complete with housing. Instrumentation, both classical (thermocouple, heat flux gauge, etc.) and sophisticated (infrared camera), is being developed and installed for a range of tests. A significant result of this program will be a ventilation guide for the designers of such installations. Another study in this domain examines the variation in the properties of the transformer cooling oil (QS 8529A) at temperatures as low as -60°C.

In order to calculate the heat transfer situation and, thus, the resulting current-carrying capacity of underground distribution cables, a computer program was developed using a system of finite elements and automatic mesh generation to calculate the temperature field surrounding a duct bank. This program can accommodate any size or shape of these devices. In collaboration with Ontario Hydro, IREQ is carrying out a multiyear contract for CEA to perform experiments in the Institute's full-scale duct-bank facility with a view to developing a computer program for predicting the thermal behavior of underground cables under cyclical load conditions.

Another of the group's major interests is the biomass program, which involves studies of the conversion of peat moss and wood residues into synthetic gas that could be used to produce methanol or a fuel for remote diesel-generator installations. In 1983, the team designed and began construction of a pilot gasification reactor involving two gas generators operating on the fluidized-bed principle. These devices are part of a larger-scale project in which Biosyn is also involved.

In the solar energy field, work continued at a modest level on an evaluation of flat-plate collectors using a liquid coolant, and the results were used to validate a simulation program. Progress was also made in the generation of a meteorological station concept.

The on-going thermal energy studies are important in that they permit new techniques to be developed and keep the group abreast of advances in the thermal science fields. For example, during 1983 the development of a system of infrared television was initiated for visualizing temperature fields; the first application of this capability is expected to be the transformer cooling project mentioned above, but it could also be incorporated into the industrial heating program. In addition, a low-velocity wind tunnel was brought to operational status. Finally, evaluation and calibration of certain measurement devices such as a heat flux gauge and anemometer systems were undertaken in the group's facilities.

Publications and Technical Reports (see insert)
CP 30, 31, 67, 97, 111, 122
TR 16, 38, 39, 53, 60, 70, 71, 94, 96, 104, 107, 110

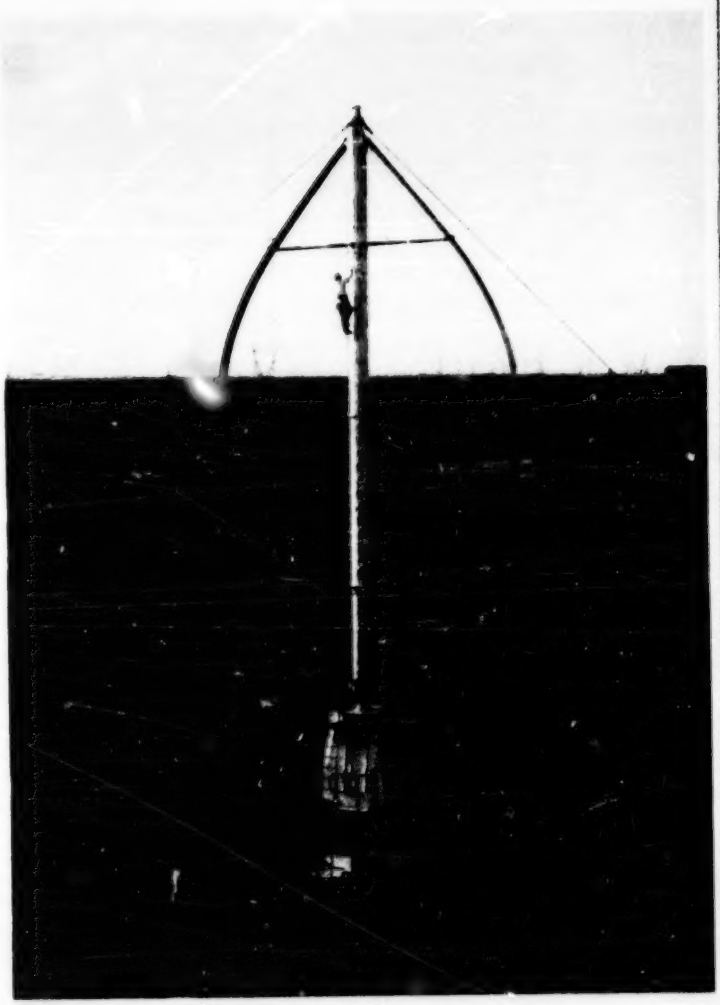
Wind Turbines

Manager
Albert Watts

The past year's activities were devoted almost exclusively to the development and operation of large Darrieus wind turbines.

The analytical and experimental research in 1983 centered around Project *EOLE*, a large-scale undertaking as will be seen below, and the installation of a 56-kW Darrieus-type wind turbine at IREQ.

Project *EOLE*, which is jointly funded by the National Research Council (NRC) and Hydro-Québec, involves the design, construction and evaluation of the largest Darrieus wind turbine prototype in the world. With a capacity of 4 MW, the machine will have a rotor 64 m in diameter and 96 m high. IREQ will maintain general responsibility for the project while Hydro-Québec's Engineering and Construction division will handle the management; Shawinigan Consultants Inc. will carry out the engineering work involved. Initiated in 1981, the project has made very satisfactory progress over the past 12 months. The preliminary-design phase was completed in March with a systematic review of the work achieved thus far. This was followed by a series of studies to locate a suitable site for the wind turbine; the one finally selected is near Cap-Chat in eastern Québec. By September-October, the engineering work had reached the stage where invitations to tender could be made for manufacture of the electrical components and the rotor. The construction date is scheduled for the late summer 1985 with commissioning due to take place the following fall.



Installation of a 56-kW Darrieus wind turbine.

The other achievement of 1983 was without a doubt the installation of a 56-kW Darrieus wind turbine at IREQ, which provides the Institute with a research facility for pursuing its studies on this type of machine. It will be used for collecting data on the dynamic performance of the various components, which will then serve to check the analytical models IREQ is now developing and, also, to design wind turbine components, in particular for Project *EOLE*. The 16.8-m high rotor with its 11.2-m diameter will have the same profile as the *EOLE* prototype. It is a commercial product which has been modified to allow testing of three- or six-guy wire configurations at different velocities. It will also be equipped with instruments for studying the aerodynamics, structural dynamics (rotor and guy wires) and dynamic behavior of the drive train and control system. Initial studies on the guy system are due to commence in the beginning of 1984.

Responsibility for the Magdalen Islands 230-kW Darrieus wind turbine has now been handed over to the Matapedia Region for operation on an experimental basis as a generating unit supplying the local grid. Meanwhile, the group is exploring the possibility of setting up a 3-MW wind farm in the Magdalen Islands comprising six aerogenerators of the same type as the one already installed but more sophisticated in design. Hydro-Québec has already conducted site studies and taken wind measurements for this purpose, while Energy, Mines and Resources Canada has been approached for subsidies to share the cost of this project and increase its cost-effectiveness for Hydro-Québec. It is planned to initiate the preliminary-design phase early in 1984 and to proceed with installation the following year.

The analytical studies and mathematical modeling needed for wind turbine design and their integration into electrical power systems were pursued largely in relation to Project *EOLE*. They include calculations of the aerodynamic performance and forces of Darrieus wind turbines, forecasting of the dynamic performance of the rotor and guy wires of these machines, simulation of the dynamics of wind energy systems connected to electrical grids and the development of calculation methods for the contribution, load management and cost-effectiveness of wind turbines used to supply electrical power systems.

Publications and Technical Reports (see insert)
CP 14, 46, 92, 105, 113, 143
PU 37, 38, 39
TR 4, 5, 12, 33, 42, 43, 71, 84, 86, 89, 93, 108, 111
AD 19, 22, 23

Fusion

Manager
Richard Bolton

Fusion technology is based on the development of two plasma confinement methods, one magnetic, the other inertial. IREQ's activities in this area deal mainly with magnetic confinement, and are focused in particular on closed configurations, of which the tokamak represents the most promising model at the present time.

The *Tokamak de Varennes* project, which embraces the design, construction and operation of a research and development device functioning in a quasi-continuous mode, is by far the principal activity. Carried out under the responsibility of IREQ, the project involves close collaboration with the *Institut national de la recherche scientifique (INRS-Énergie)*, the University of Montreal, Canatom Inc. and MPB Technologies Inc. Hydro-Québec and NRC share the costs estimated at approximately $38 million while the university partners, for their part, contribute half their respective labor costs.

The tokamak machine will be modest in size (major radius of 0.86 m) and will operate with ordinary hydrogen but it will be unique in that it is designed to function in a quasi-continuous mode, which consists of a train of closely spaced plasma current pulses of alternating polarity. This will allow studies of the influence of high-duty-factor operation on plasma/wall interactions and on the accumulation of impurities during discharge.

Computer room where most of the scientific work on the Varennes tokamak project is carried out.

In September 1983 the manufacturing contract for the toroidal and the poloidal field coils for the tokamak was awarded to Marine Industries Ltd. of Sorel, Québec. (Delivery is scheduled for fall 1984.) Meanwhile the bids for the vacuum chamber have been analyzed in detail and the contract should be awarded early in 1984. The tenders for the power supplies have also been studied, although a number of adjustments are now called for if the original budget is to be respected. The project computers began to operate 24 hours a day in 1983 and are now being used for most of the scientific, technical and administrative tasks. In fact the main computer is used to control all the procurement and financial aspects of the project, assuring better follow-up and a more accurate estimate of future costs.

With regard to construction of the research facility, the test cell is now ready for installation of the tokamak, except for the machine support structure and the control room. Construction of the tokamak is scheduled for completion in 1985.

Meanwhile the group's theoreticians have pursued their research on the RF (radiofrequency) heating of tokamak-type plasmas, in collaboration with MIT and the Culham fusion laboratory in England. In the course of digital studies using the Fokker-Planck equation, an unexpected broadening of the resonant region was noted, which results in an increase in the number of particles carrying the current induced by the application of an RF field. As for experimental studies of RF heating, funding for the proposed electron cyclotron frequency heating option unfortunately has still not materialized.

With regard to laser fusion, work continued over the year on a project initiated with *INRS-Énergie*. The aim of this project is to measure the coupling efficiency and energy laser-plasma interaction. Improvements to the ion filtration techniques have made it possible, at last, to obtain detailed fast-ion measurements with a pinhole camera.

In another project dealing with optical methods for hot-plasma measurement, the group has used infrared scattering for measuring the ion temperature of a laboratory plasma. Based on heterodyne techniques and spectral analysis of the RF signal in a 1-GHz band, this measuring method was successfully applied to a dense-plasma column. A CO_2 laser served as the radiation source.

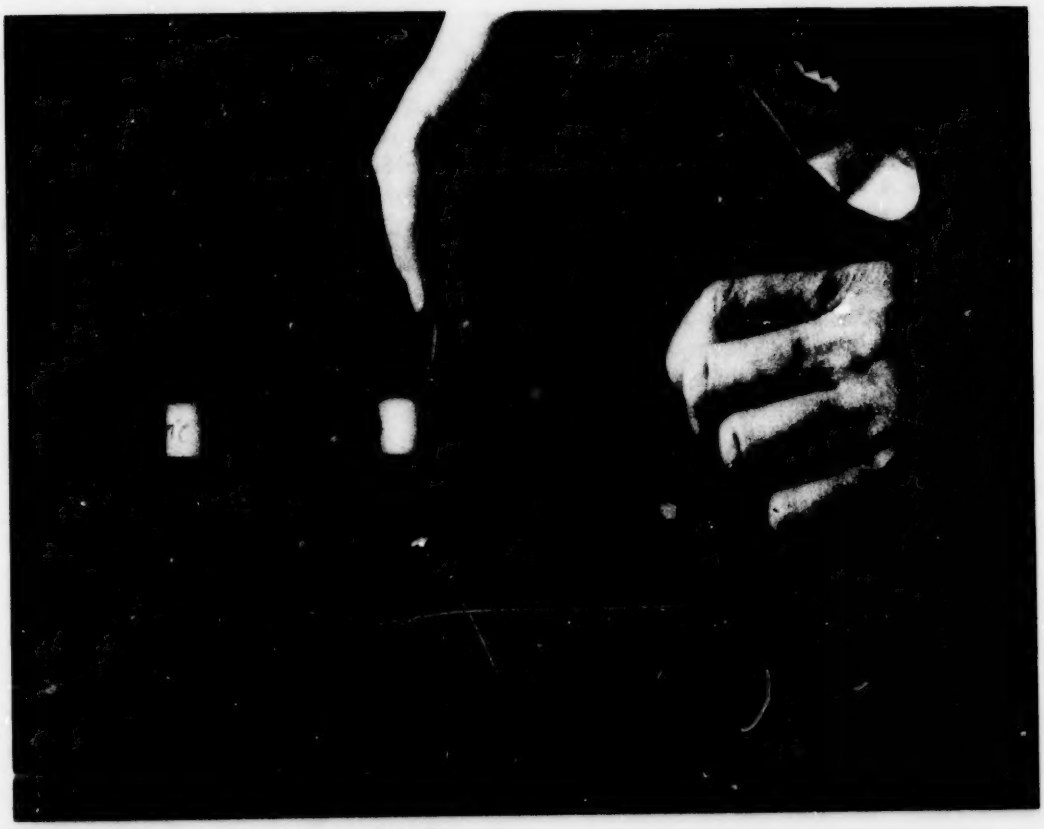
Publications and Technical Reports (see insert)
CP 23, 29, 37, 42, 43, 54, 58, 59, 70, 71, 72, 73, 93, 123, 124, 125, 126, 144
PU 12, 13, 16, 21, 22, 23, 44, 45, 46, 47
TR 51, 77
AD 6, 10, 21

Hydrogen and Electrochemistry

Manager
Guy Bélanger

The two main axes of the research, development and demonstration activities of this group are electrochemistry and domains related to the production, storage and utilization of hydrogen as an energy carrier.

The group's effort in the area of electrochemistry consists largely of research and demonstration activities, with the polymer-electrolyte battery program mobilizing most of the personnel. This program involves close collaboration with the *Société Nationale Elf Aquitaine* (*SNEA*) and the University of Grenoble in France. In 1983 IREQ signed a pre-development contract with *SNEA* under which laboratory prototype batteries will be built over the next four years. Meanwhile a final technical report was completed during the year bringing to an end a contract undertaken with the Canadian government aimed at resolving the lithium electrode rechargeability problem. This involved evaluation of a series of lithium-M alloys (M = aluminum, tin, lead). At the basic-research level, the lithium activity in such alloys was determined and phase diagrams were established.



Verification of an encapsulated polymer-electrolyte battery module.

The group has also designed and built equipment for the quasi-continuous production of electrodes and large electrolyte films. Charge/discharge tests are now under way on encapsulated modules which can be handled outside the controlled-atmosphere glove boxes. Progress in the work on polymer characterization and synthesis now enables the group to define more accurately the materials employed and to proceed to the evaluation of the new polymers.

Other electrochemistry-related activities during the past year included the synthesis and evaluation of electrocatalytic materials for hydrogen evolution reactions during the electrolysis of water in an alkaline medium. The same nickel- and cobalt-based materials will also be assessed from the point of view of their activity in the oxygen reduction process in fuel cells.

Mention should be made of the group's interest in photoelectrochemistry, its activities here consisting of tests on oxide-based compounds of metals such as cobalt, chromium, tantalum and aluminum. On a more theoretical level, it is currently evaluating oxides in arcs and on demetallized surfaces and studying their role in the electrochemical deposition of cadmium and similar phenomena. In another area, theoretical and experimental models of copper dissolution in bromide media have been developed on the basis of the behavior of this metal in contact with chlorinated solutions. Meanwhile, the relaxation technique was applied to determine the diffusion of oxygen ions in TiO_2-type materials following changes in the oxygen partial pressure. As a result of improvements both to the test techniques and to the data processing system, rapid determination of the parameters of interest is now possible. Finally, work was completed on a high-temperature dry oxidation process for materials that could be used as solar collectors; it is now planned to patent this process.

In the area of insulating oils, some fifty Hydran 201 hydrogen detectors have been installed on Hydro-Québec transformers. These recently developed monitors measure the concentration of dissolved hydrogen in transformer oil. The group is now engaged in collecting and processing all the pertinent data. It is also carrying out various tests to finalize an *in situ* measuring system designed to determine the water content in transformer oil and insulating paper. A number of tests have been performed on a means of temperature measurement based on the chemical decomposition of oil additives which produce either carbon monoxide at 110°C or nitrogen at 130°C. These tests were performed during an overload study on 25-kV distribution transformers and a 170-MVA power transformer.

The year 1983 saw the completion of work on the characterization of electrical contacts based on the use of aluminum. The final report to CEA on this project deals mainly with the measurement of changes in resistivity between an aluminum wire and a metal plate (aluminum, silver, sodium, nickel, zinc, cadmium, tin, copper, brass and bronze). The contacts under study were subjected to continuous fretting at various frequencies and amplitudes. These electrical measurements were completed by surface analyses using spectroscopic and microscopic techniques. CEA has now awarded further contracts, this time for the characterization of mechanical-contact techniques (bolts, screws, washers) and lubricants (grease).

The hydrogen-related activities in 1983 consisted chiefly of demonstration projects, the most important being the operation of IREQ's electrolysis pilot plant. An evaluation of hydrogen compression systems was conducted for the Institute, while a study was completed for CEA on the performance of a 3-kW electrolyzer with a random input.

Progress in the hydrogen utilization project took the form of the purchase of a 40-kW fuel cell which will be supplied with hydrogen directly from IREQ's electrolyzer. United Technologies is scheduled to deliver the fuel cell next summer.

As far as research is concerned, a project was initiated to study catalytic reaction mechanisms and to evaluate the catalysts used in the reduction of CO by hydrogen in the presence of CO_2 (which results in synthesis of organic fuels such as methanol or light hydrocarbons). Finally, it should be mentioned that catalyst characterization and reactor vessels for methylcyclohexane dehydrogenation as a hydrogen storage system are still under study at *École Polytechnique de Montréal*.

Publications and Technical Reports (see insert)
CP 15, 16, 17, 18, 24, 25, 26, 27, 28, 50, 60, 80, 81, 90, 101, 108, 112, 130, 142
PU 4, 7, 8, 9, 10, 17, 31, 51 ,52, 53, 54, 55, 56
TR 6, 31, 60, 69, 97, 106, 107
AD 2, 3, 9, 11, 16

Electrical Insulation

Manager
Hugues St-Onge

Research on electrical insulation in 1983 dealt with solid (composite insulators, stator windings of rotating machinery, extruded cables) and liquid (cables) insulation systems, as well as oil-impregnated systems (transformer oils, EHV cables and capacitors). The physico-chemical aspect of electrical insulation is equally a source of interest.

Over the last year, the group has pursued a study initiated in 1978 on the long-term behavior of composite insulators for 735-kV transmission lines. This involves studies of the creep resistance of four types of insulator on indoor and outdoor traction benches, the latter designed to allow exposure to variable climatic conditions and voltage applications for accelerated-aging purposes. Results have been obtained for test periods of up to 20 000 hours. This was the fourth year of the group's investigation into the aging of insulator skirt materials and the effects of acid rain on insulator failure mechanisms. Now under study for CEA is the behavior of composite insulators under three types of pollution conditions with a view to developing an accelerated-aging test procedure for the laboratory. Another related study was undertaken in the past year in collaboration with Toshiba Corporation, Japan, on the mechanical integrity of epoxy-impregnated fibreglass systems.

Study of the effects of pollution on the performance of synthetic insulators.

Research on techniques for determining the aging and degradation of the stator windings of rotating machinery was also pursued in 1983 using a partial-discharge analysis technique developed by CEA. Meanwhile a research and test program was initiated for Battelle Colombus Laboratories for the purpose of characterizing extruded cable with solid insulation which has experienced in-service failure. Dielectric breakdown tests on aged cross-linked polyethylene cables should also begin in the near future with a view to obtaining a better understanding of extruded-cable aging. In the context of another research project, this one in cooperation with *École Polytechnique de Montréal*, work continued on high-temperature conduction and breakdown in polyethylene.

In the field of EHV liquid-oil-filled cables, the group carried out investigations for Hydro-Québec aimed at determining the significance of dissolved gases in the oil of in-service cable.

The long-term objective here is to forecast and prevent fault occurrence on underground systems. In addition, work was initiated this year on the compatibility of new cable oils for Hydro-Québec's 315-kV underground system. Research on the development of decision-making criteria for EHV cable maintenance should begin very shortly. These projects mark yet further milestones in the close collaboration that has existed in recent years between IREQ and Hydro-Québec's various engineering and EHV cable operating divisions.

Research in 1983 on impregnated-insulation systems was oriented towards the replacement of conventional naphthenic transformer oils. A major research program undertaken for CEA focused on the low-temperature performance and long-term behavior of paraffinic oils derived from Canadian crude.

In parallel, a project in collaboration with the *Centre de Physique Atomique de Toulouse* (France) on silicone oils was brought to a close and it is now planned to launch a joint study program on transformer aging using scale models. With regard to power capacitors, the group completed a review of all the work performed at IREQ on the thermal aging of polypropylene films.

Several problems were addressed in the course of the year's research on the physicochemical characteristics of electrical insulation. For example, the behavior of Voltesso-35 transformer oil exposed to artificial lighting was investigated, while a study began on the oxidation stability of reclaimed oil with a view to formulating better criteria for oil regeneration. An IREQ-developed automatic analysis system for anti-oxidants in oil was further improved in 1983, while a study of the physicochemical behavior of SF_6 in the presence of polymers was pursued in the partial-discharge mode. A new analytical technique for measuring SF_6 degradation products at concentration levels as low as 0.05 ppm was also developed. Research continued on the influence of dissolved salts and humidity on the initiation of electrochemical tree growth in distribution cables. Finally, mention should be made of a study under way on the role of osmotic pressure in the tree growth process and the development work for EPRI on diagnostic techniques to study extruded-cable insulation aging.

Publications and Technical Reports (see insert)
CP 36, 38, 39, 40, 47, 81, 94, 95, 98, 106, 116, 128, 138
PU 3, 24, 30
TR 14, 15, 18, 19, 23, 24, 37, 55, 56, 57, 60
AD 5, 7, 8, 25

Metallurgy and Nuclear Technology

Manager
Raymond Roberge

This group's activities in 1983 were both multiple and diverse, covering as they did some 38 projects of development, demonstration, testing and consultation. These fall under the headings of metallurgy and materials technology, the transfer of technology, and chemistry related to nuclear equipment.

Materials engineering forms the basis of research aimed at countering erosive cavitation in hydraulic turbines. A new type of stainless steel with a low cobalt content has been formulated, cast and evaluated in the laboratory with a view to replacing the stainless steel now used to protect areas of intense cavitation. This new alloy should prove less costly than the conventional cobalt alloys used in turbines while providing ten times more resistance to erosive cavitation than stainless steel 304. In addition, development work on an electrochemical erosive-cavitation detector, carried out through cooperation between France and Québec, has resulted in a better material being selected for this device. The activation-current signal is directly proportional to the erosion rate over more than three orders of magnitude, i.e. from 0.1 to 100 mm/year. The detector was successfully tested at Hydro-Québec's Bersimis I generating station and improvements were made to its microprocessor-based instrumentation.

The group's activities in the area of welding included a study aimed at obtaining a better understanding of plasma-weld pool interaction phenomena that appear during electric-arc welding. In addition, as part of a contract for NRC, it has developed a device for real-time measurement of the length and depth of the weld pool. Another project involved the design, construction and testing of an automatic welding system for making cases for experimental batteries. Meanwhile, work is still under way on the robotized gouging of turbine blades in a project undertaken in collaboration with Systems Engineering. Tests on the new ultralightweight gouging torch provided a satisfactory indication of its reliability.

Expertise in the field of fracture mechanics and material fatigue has been consolidated. In collaboration with ASTM, the group completed two draft standards on test methods, while a project partially funded by CEA should lead to the formulation of recommendations with respect to the fatigue properties of ACSR conductors, these recommendations to be based on experimental results for single strands and actual-sized conductors and the development of a theoretical model.

In another area, the evaluation of new magnetic materials has led to a novel transformer design comprising a wound magnetic circuit which allows large savings on materials. Work was pursued on the development and characterization of *in-situ* superconducting alloys. The use of the heat of hydration of inorganic salts is also under study for application to seasonal storage of solar energy as well as to industrial heat pumps for upgrading low-temperature waste heat. In addition, the group is assessing the scope of activities required to meet the utility's needs with respect to concrete and cement.

Among the many services provided by the group in relation to the design, standards, fabrication or maintenance of materials, mention might be made of the following: the mechanical testing of a new prototype boom extension for bucket trucks; a study of the failure mechanism of porcelain insulators in electrical substations; use of the finite-element method to calculate the stresses and deformation in a guyed cantilever conductor crossbar of laminated wood; evaluation of an acoustic emission technique during mechanical testing of composite insulators; the

Design of a new distribution transformer with a wound magnetic circuit.

metallurgical and mechanical characterization of a number of materials and materials systems; many analyses of in-service failure; a study of the causes of corrosion in anchor systems and ground rods due to circulating DC currents and the formulation of solutions; determination of the best type of brazing to use for assembling the copper conductors used for underground transmission cables; and the development and optimization of a welding process for repairing turbine shafts rather than replacing them as soon as cracks appear. In addition, metallurgical, mechanical and physical characterization projects were carried out for many Québec firms.

With regard to nuclear technology, a 100-m² radioisotope laboratory was set up during the year and is now being put into operation. Personnel training is under way along with the drafting of procedures. The laboratory will be used for studies on decontamination, corrosion, water chemistry and radio-element sorption phenomena. It can be pointed out in the context of work in this field that the results of a study on the dissolution mechanisms of magnetite in suspension in a complexing solvent have enabled various mechanisms to be identified according to the pH of the medium. In response to requests from Hydro-Québec's Gentilly 2 nuclear generating station, the group has designed, built and performed laboratory tests on a sensor for measuring the gadolinium nitrate content in the nuclear reactor emergency shut-off system. Finally, the use of this sensor for examination of the corrosion of structural materials at the Gentilly 2 plant is planned, starting with a project on stress corrosion in the 800 series of alloys used in steam generator tubes.

Publications and Technical Reports (see insert)
CP 1, 6, 7, 8, 9, 10, 11, 12, 13, 24, 32, 51, 52, 53, 55, 63, 78, 79, 82, 83, 84, 102, 103, 107, 116
PU 1, 2, 18, 25, 30, 32, 34, 35, 40, 41, 42
TR 19, 32, 79, 95
AD 1, 17

REQ

PLANNING and MARKETING

Acting Manager
Gérard Juneau

This department is responsible for technological forecasting and planning and for selecting the appropriate methods for conducting technical and economic studies. It also handles the marketing of technology and products developed by Hydro-Québec.

As in the past, the department was responsible for coordinating the preparation of Hydro-Québec's technology development plan, which outlines the strategies to be followed with respect to research programs and resources needed in order to fulfill the company's objectives. This involved multiple scenarios and participants from many departments of Hydro-Québec, with the result that computer programs had to be developed, which can of course be used for similar treatment of subsequent technology development plans.

In 1983 the group also performed a number of strategic studies. Its technical and economic studies in fact enabled IREQ management to define its policies on industrial applications of electricity in such areas as paper making and drying, and ladle preheating and slab heating in steel plants. Such studies should result in industrial pilot installations being set up.

The department took an active part in negotiating the transfer of *Electricité de France's* infrared and induction expertise to IREQ to enable the Institute to intervene directly in the development of these technologies.

Among the major contracts signed in the course of the past 12 months, mention could be made of the following:

- purchase of plasma technology from Noranda
- agreement with a French firm, *SNEA*, on the predevelopment of polymer-electrolyte batteries
- technical-assistance contract with *CEPEL* to be financed by CIDA
- collaboration agreement with *Électricité de France*
- agreement with *CODATEL* for the construction of test benches and research work on the industrial applications of infrared and plasma technologies.

In addition to these, of course, are the many research contracts signed with such organizations as CEA, Supply and Services Canada, and EPRI.

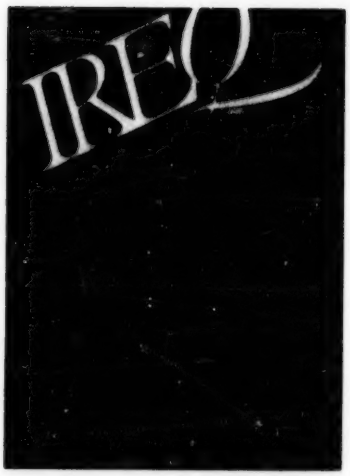
During the year, IREQ increased its participation in the final design of various products in an attempt to accelerate the marketing process. Furthermore IREQ sent representatives to several exhibitions, including technology-transfer expositions in Gand, Paris, Toulouse and Montreal, and other more technical exhibitions related to welding, software and power-system planning in Philadelphia, Houston and Montreal. An observer was also sent to an industrial fair held in Hanover, West Germany. The Institute hopes to attend more technical and commercial expositions in future in order to increase its share in the marketing of technologies.

Among other activities in 1983, a technology marketing plan that takes account of the utility's major concerns was drafted and submitted to the vice-president, IREQ.

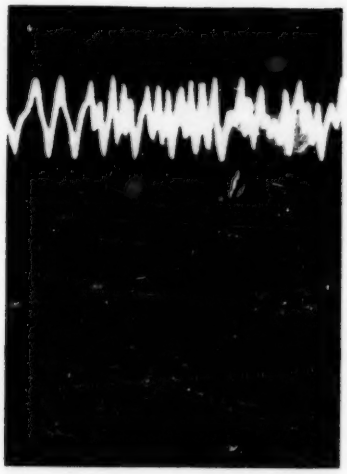
The department believes that the successful marketing of new products and technologies developed at Hydro-Québec depends on close cooperation between the utility, IREQ and Québec industry in the design, testing and development of industrial prototypes. It will work towards increasing this collaboration in the coming year.

1983, IREQ participated in technology-transfer hibitions in France, Belgium, the United States d Québec.

IREQ...is first and foremost its personnel.



A detailed description of the Institute's laboratories and installations may be found in the brochure *IREQ Research and Testing Facilities.*



For its part, the brochure entitled *Research* describes the more important research activities undertaken at IREQ together with the services made available to its clients.

Both documents can be obtained free of charge on request by contacting the Resources and Information department at IREQ.

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